In Press, Neuropsychologia

Strategic use of reminders in an 'intention offloading' task: Do individuals with autism spectrum conditions compensate for memory difficulties?

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Keywords: intentions, prospective memory, autism, metamemory, metacognition

Acknowledgements:
SJG was supported by a Royal Society University Research Fellowship.

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Previous studies have found that individuals with autism spectrum conditions (ASC) can have difficulty remembering to execute delayed intentions. However, in these studies participants were prevented from setting external reminders, whereas the use of such reminders in everyday life is commonplace (e.g. calendars, to-do lists, smartphone alerts). In the present study, 28 participants with ASC and 24 matched neurotypicals performed a task requiring them to remember delayed intentions. In the first phase participants were required to use unaided memory, whereas in the second they had the option to offload their intentions by setting reminders if they wished. Performance of the ASC group was significantly poorer than the neurotypical group in phase 1, and metacognitive evaluations of memory abilities mirrored this. Nevertheless, in the second phase, the ASC group failed to compensate for impaired performance: if anything they set fewer reminders than the neurotypical group. These results indicate that intact explicit metacognitive judgements cannot be assumed to lead directly to the use of compensatory strategies.

1. Introduction

1.1 Prospective memory

Prospective memory is an umbrella term describing the processes that enable us to execute delayed intentions, such as remembering to add an attachment to an email before sending it, or to attend a planned future appointment (Brandimonte et al., 1996; Kliegel et al., 2008; Kvavilashvili, 1987; McDaniel and Einstein, 2000; Meacham and Leiman, 1982; Scullin et al., 2015). These processes play a key role in behavioural organisation, allowing us to defer behaviours that cannot immediately be executed and pursue goals over extended periods of time. In this way, prospective memory contributes to our ability to live independently and purposefully. Here, we investigate prospective memory in adults with autism spectrum conditions (ASC). In particular, we ask the following question: insofar as individuals with ASC have difficulty with prospective memory, to what extent do they compensate for this when appropriate strategies are available?

1.2 Autism spectrum conditions

Individuals with ASC tend to show impairment on executive function tasks (Hill, 2004a, 2004b; Ozonoff et al., 1991; Ozonoff and Jensen, 1999; Russell, 1997; Russo et al., 2007), i.e. tasks requiring behavioural regulation and control. This is particularly the case when they are "ill-structured" or "open-ended" (White et al., 2009). Memory difficulties have also been reported (Ben Shalom, 2003; Boucher et al., 2012; Lind, 2010), especially in tasks involving self-initiated retrieval of information, as opposed to externally-cued recognition tasks (Bowler et al., 2000a, 2000b, 1997; Gaigg et al., 2008). Prospective memory can be seen as involving executive functioning (because individuals typically have to interrupt one activity and switch to another intended activity) and also retrospective memory (because individuals then need to remember the content of their intention). It also places high demands on self-initiated processing (Craik, 1986), because typically intentions are not strongly triggered by external cues. Therefore it might be expected that individuals with ASC would have difficulty with such tasks. This has been confirmed in several recent studies.

Studies investigating laboratory-based prospective memory tasks in children and adolescents with ASC have generally found that their performance is impaired in comparison with neurotypical controls (Altgassen et al., 2009; Brandimonte et al., 2011; Henry et al., 2014; Jones et al., 2011; Mackinlay et al., 2006; Rajendran et al., 2011; Sheppard et al., 2016; Williams et al., 2013; Yi et al., 2014). The difficulties of children with ASC may be particularly pronounced for time-based tasks (where something needs to be done at a particular time) rather than event-based tasks (where something needs to be done when a particular cue appears; Henry et al., 2014; Williams et al., 2013). Similar results have been obtained in adults (Altgassen et al., 2012; Kretschmer et al., 2014), again showing a particular impairment in time-based tasks (Williams et al., 2014). A key question raised by these studies is the extent to which individuals with ASC are able to use strategies to compensate for impaired prospective memory ability (Altgassen et al., 2012). It has been suggested in particular that relatively good performance in event-based tasks may relate to strategic compensation (Williams et al., 2014). However, previous studies have not directly measured strategic compensation and have prevented participants from using a prominent form of strategic behaviour that can be used to promote fulfilment of delayed intentions.

1.3 Intention offloading

One characteristic shared between the studies reviewed above, along with the vast majority of studies investigating prospective memory in general, is that participants are required to remember delayed intentions without the aid of any external tools or reminders. By contrast, in everyday life external prompting of delayed intentions is commonplace (Hall et al., 2013; Harris, 1980), with tools such as diaries, planners, to-do lists, and smartphone alerts (Svoboda et al., 2012). Individuals can improve their ability to remember delayed intentions, or compensate for prospective memory impairment, using tools such as these. Therefore, just because a particular group has difficulty remembering delayed intentions when they are prevented from using external reminders, this does not necessarily mean that they would have a similar impairment in everyday life, when they are able to use compensatory memory aids. This may help to explain the finding that older adults tend to perform better on real-world prospective memory tasks than laboratory-based ones (although it cannot provide an exhaustive explanation of this phenomenon; Phillips et al., 2008). Individuals with impaired unaided memory abilities might not show any functional impairment when they have the opportunity to compensate. Alternatively, any impairment might be exacerbated if impaired individuals use memory aids less than unimpaired individuals. In the present study, we investigate whether any impairment of individuals with ASC in remembering delayed intentions is reduced, increased, or unaffected by the option to set external reminders.

The process of setting up an external cue to prompt intended behaviour is known as 'intention offloading' (Gilbert, 2015a, 2015b; Landsiedel and Gilbert, 2015; Risko and Gilbert, 2016). This process has been investigated using the task illustrated in Figure 1. In this task participants perform a series of trials, on each of which they are required to remember a delayed intention, with the option to set an external reminder if they wish.

Gilbert (2015a) showed that even though the retention interval in this task is only a few seconds, it significantly predicted fulfilment of a real-world intention to visit a specified website one week later in order to receive a small bonus payment. This demonstrates its external validity with respect to naturalistic prospective memory tasks embedded within participants' everyday lives. Not only did the intention offloading task significantly predict real-world prospective memory, it had greater predictive validity than more traditional event- and time-based prospective memory tasks. This may relate, at least in part, to its ability to capture variance related to strategic intention offloading behaviour that influences real-world prospective memory but is prevented in standard prospective memory tasks. It could also relate to the way that this task uses a novel delayed intention for each trial, rather than a single intention throughout (see Gilbert, 2015a, for discussion).

This task can be used to investigate the factors that influence participants' choice to use or forgo external reminders, and the effects of reminders on performance. Gilbert (2015a) found that intention offloading led to improved performance, and that individuals were more likely to offload intentions when they encountered a higher memory load, or an interruption between encoding an intention and an opportunity to act on it. These same factors increased the number of errors when participants were prevented from setting reminders. This suggests that participants may set reminders in order to compensate for factors that make errors more likely (see Risko & Dunn, 2015, for a related finding in a short-term memory task).

[Figure 1 about here]

1.4 The role of metacognition

How do we decide whether to set an external reminder for a delayed intention, or simply rely on unaided memory? Recent evidence suggests that metacognitive processes play a key role. Metacognition refers to our ability to monitor and evaluate our own mental processes, and use these evaluations to influence behaviour (Dunlosky and Metcalfe, 2008; Flavell, 2000; Koriat, 2007; Metcalfe, 1996; Nelson and Narens, 1990). Theoretical views of metacognition (Flavell, 1979) make a distinction between metacognitive knowledge (our beliefs and knowledge about our own minds) and metacognitive control (the use of those beliefs and knowledge to influence behaviour). These two aspects of metacognition are potentially dissociable (e.g. Dunlosky & Connor, 1997), but both would be required in order to make appropriate use of external reminders. Metacognitive knowledge is required in order to evaluate whether our unaided memory abilities are sufficient or whether external support is needed. If external support is needed, metacognitive control would then be needed to actually influence the choice of appropriate strategies.

Evidence for metacognitive influence on intention offloading comes from a study by Gilbert (2015b) in which participants first performed the intention offloading task without being able to set reminders, then in a second phase performed the task with the option to do so if they wished. Before each phase, participants reported their confidence in their ability to remember intentions. Results showed that participants' confidence in their unaided ability in phase 1 significantly predicted their propensity to set reminders in phase 2, even after controlling for any influence of objective ability (which also predicted intention offloading behaviour). This finding is consistent with evidence from various perceptual and memory tasks in which participant's confidence in their abilities predicts their use of physical action in order to reduce the cognitive load of the task (Risko &

Dunn, 2015; Risko, Medimorec, Chisholm, & Kingstone, 2014; reviewed by Risko & Gilbert, 2016). Thus, metacognitive difficulties in ASC could potentially lead to suboptimal use of external memory support.

1.5 Metacognition in autism spectrum conditions

Individuals with ASC have well-known difficulties with representing the mental states of other individuals (Baron-Cohen et al., 1985; Leslie and Frith, 1988; Tager-Flusberg, 2007). According to some authors, the metacognitive processes involved in representing our own mental states overlap at least partially with those we use to represent the mental states of other people (Carruthers, 2009; Gopnik, 1993). Therefore, it has been suggested that individuals with ASC, as well as having difficulty representing the mental states of other individuals, may also have a metacognitive difficulty representing their own mental states (Frith and Happé, 1999).

One line of evidence supporting this claim has involved adapting classic theory of mind tasks so that participants, instead of reporting the false belief of another individual, need to report their own previously-false belief (Baron-Cohen, 1991; Fisher, Happé, & Dunn, 2005; Russell, Hill, & Franco, 2001; Williams & Happé, 2009; see Williams, 2010 for a review). However, these studies suffer from the limitation that they test individuals' ability to remember and report a prior mental state, whereas metacognition is typically considered to involve representation of one's current mental state (Carruthers, 2009; Nichols and Stich, 2003).

An alternative approach has been to investigate confidence judgements in individuals with ASC as they perform various tasks. Wilkinson et al. (2010) found that the confidence judgements of children with ASC, but not adults, were less accurate than neurotypical individuals in a face recognition task. Wojcik et al. (2011) asked children to report their confidence in their performance of an action imitation task. This study found no group difference in metacognitive judgements. Cooper et al. (2016) found that adults with ASC had reduced metacognitive accuracy for one source memory task (perceived/imagined discrimination) but not another (self/other discrimination). Sawyer et al. (2014) investigated both metacognitive monitoring in an emotion recognition task (i.e. confidence ratings) and also metacognitive control. The latter was operationalised as the choice to withhold low-confidence answers rather than risk losing points for incorrect responses. Sawyer et al. found no group differences on either measure (though see Grainger, Williams, & Lind, 2016 for further discussion of this study). Finally, Grainger et al. (2016) investigated both metacognitive knowledge and metacognitive control in a quiz task, finding that children with ASC were impaired on both measures. In other words, children with ASC not only had a smaller difference in confidence between correct and incorrect responses, they also made less use of their confidence ratings when deciding which answers to submit or withhold.

The studies described above investigated participants' ability to distinguish individual trials on which they have high versus low confidence. An alternative approach is to investigate participants' general confidence in their ability to perform a task across multiple trials. This ability to evaluate enduring aptitudes and abilities, rather than distinguish confidence levels on an item-by-item basis, may be particularly relevant to participants' decisions whether or not they need external memory aids to remember delayed intentions (Gilbert, 2015b). The possibility that these types of self-evaluations may be atypical in individuals with ASC has been investigated in two recent studies. Furlano et al. (2015) investigated both objective performance and self-evaluated performance of academic tasks in a group of adolescents with ASC and typically developing controls. They found that the ASC group tended to show positively biased self-evaluations, whereas the control group was more accurate. This suggests that individuals with ASC may be overconfident in their evaluations of mental abilities, which could potentially lead to insufficient use of external aids to compensate for memory difficulties. However, in a study directly investigating evaluation of memory performance, Elmose and Happé (2014) found that children with ASC were as accurate as typically developing controls, and showed no significant difference in confidence. Furthermore, studies that have directly asked participants to rate their prospective memory abilities have found reduced confidence in individuals with ASC (Altgassen et al., 2012; Williams et al., 2014).

In sum, studies of metacognitive evaluation and metacognitive control in individuals with ASC reveal no consistent pattern, with some studies suggesting impairment in ASC and others finding no group differences. This inconsistency may result from wide variations between studies in experimental paradigms, measures, and participant characteristics (e.g. age). Therefore, in the present study we collected multiple metacognitive evaluations in order to compare individuals with ASC and neurotypical controls across several measures. Along with standard explicit measures of metacognition, where participants are directly asked to evaluate some aspect of their performance or ability, we also collected an implicit measure that sought to detect individual differences in confidence without explicitly asking for a self-evaluation. Our reason for including this measure was that although individuals with ASC may sometimes answer questions about another individual's mental state in a similar manner to neurotypical controls when asked to do so, they may nevertheless fail to engage in 'implicit mentalising', i.e. representing and evaluating the mental states of others even when this is not explicitly required by the experimental task (Ruffman et al., 2001; Senju, 2013; Senju et al., 2009). These findings support the proposal that there may be a distinction between implicit and explicit representations of beliefs (Apperly and Butterfill, 2009). Therefore, we investigated potential differences between individuals with ASC and neurotypical controls in measures of both explicit and implicit confidence.

1.6 Aims of the present study

Prospective memory has high functional importance in everyday life. Given that previous evidence suggests that individuals with ASC can have difficulty with prospective memory tasks, it is important to understand how far compensatory strategies can mitigate these difficulties. While some evidence points to the use of strategies and compensatory learning in individuals with ASC to mitigate underlying difficulties (Frith, 2004; White et al., 2014), other evidence suggests reduced use of strategies. For example, Loth et al. (2011) found that individuals with ASC make less use of organisation strategies to support memory recall. Intention offloading is a commonplace strategy that can transform a prospective memory task from one with high demands for self-initiated retrieval to one in which memory retrieval is directly triggered by an external cue. While individuals with ASC have difficulty with the former sort of task, they do not with the latter (Bowler et al., 1997). Therefore, we investigated whether the availability of an intention offloading strategy affected group differences in participants' ability to remember delayed intentions. Furthermore, we investigated whether individuals with ASC and neurotypical control participants differed in their metacognitive evaluation of their own abilities, which may play an important role in triggering intention offloading behaviour.

2. Methods

2.1 Participants

Twenty eight adults (4 females) with ASC and 24 neurotypicals (6 females) were recruited from the autism participant database of the Institute of Cognitive Neuroscience, University College London (UCL). Ethical approval was obtained from the UCL Research Ethics Committee and all participants gave written informed consent before taking part in the study. Participants in the ASC group had all received formal diagnosis of autism (n = 4), autism spectrum disorder (n = 4) or Asperger disorder (n = 20) from an independent clinician (psychiatrist, psychologist, or speech and language therapist). All participants in the ASC group were assessed on Module 4 of the Autism Diagnostic Observation Schedule (ADOS-G, Lord et al., 2000; ADOS-2, Lord et al., 2012) by a trained researcher with research-reliability status. Nine participants met the ADOS classification for autism, twelve for autism spectrum, and seven did not meet the classification for either autism or autism spectrum. All seven of these reached the cut-off for autism spectrum on either the Communication or Reciprocal Social Interaction subscale, and had a clear diagnostic history from an independent clinician. None of the participants in either group reported using psychotropic medication or having a history of neurological or psychiatric disorders other than ASC. The participants were matched for verbal and nonverbal ability. Two sample t-tests confirmed that groups did not differ significantly on full-scale IQ (FIQ), verbal IQ (VIQ) or performance IQ (PIQ), assessed using the full (four subtests) version of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). Groups were also equated for age (see Table 1). One participant in the ASC group did not complete the task assessing implicit confidence. All other participants completed all tasks and questionnaires.

[Table 1 about here]

2.2 Measures

2.2.1 Intention offloading task

Participants used a touchscreen-enabled laptop to perform a version of the intention offloading task adapted from earlier studies (see Gilbert, 2015a, 2015b; Landsiedel & Gilbert, 2015; for a demonstration of the task please visit "http://samgilbert.net/offloadDemo.html"). They performed the task in two phases; in the first they were not allowed to set external reminders and in the second they were. Before each phase, participants predicted how well they would perform, in order to provide separate measures of their confidence in their unaided ability and their ability when external reminders were allowed.

Each trial started with 10 numbered yellow circles positioned randomly inside a box (see Figure 1). Participants were instructed to drag the circles in sequence (1, 2, 3, etc.) to the bottom of the box using their finger. When each circle reached the bottom of the box it disappeared, leaving the other circles on screen. Only after each circle had been removed from the screen in this way could the next in the sequence be removed; therefore it was only possible to progress by performing the task correctly and there was no accuracy measure for this ongoing task. After all 10 circles had been removed in this way, the screen cleared and the next trial began. At the beginning of the task, the experimenter demonstrated the procedure and then the participant performed one practice trial.

Following this, additional instructions were presented so that delayed intentions were embedded within the ongoing task described above. At the beginning of each trial participants were instructed to drag either one (1-target condition) or three (3-target condition) of the circles to an alternative side of the box when they were reached in the sequence (e.g. 'Please drag 7 to the top instead'). This meant that they had to remember an intention to drag '7' to the top until after they had dragged numbers 1 to 6 to the bottom of the box. As a result, participants formed delayed intentions to produce nonstandard actions when they encountered pre-specified cues, in common with standard laboratory prospective memory tasks. However in this case the retention interval between encoding an intention and acting on it was much shorter than typical tasks (see Gilbert, 2015a, 2015b for discussion of this point).

Participants performed two practice trials in the 1-target condition followed by two practice trials in the 3-target condition. After this, they provided performance predictions before starting the first phase of experimental trials. They did this by dragging a slider on the screen between a "0%" and "100%" label in order to answer two questions. First they answered the question "Please use the slider below to indicate how many of the special circles you think you will remember to drag to the alternative location when you have one circle to remember", then they answered the same question "when you have three circles to remember". After this, they performed 20 experimental trials, consisting of a randomly intermixed sequence of 10 1-target trials and 10 3-target trials.

Following phase one of the task, participants were given instructions on how to offload intentions by setting external reminders. They were told: "Some people find it helpful to drag the special circles near to the edge of the box to help them remember. For example, if you had to remember to drag 5 to the left of the box, you could drag it near to there at the beginning, before you drag the 1. Then when you eventually got to 5, its location would remind you what to do. you should feel free to use this strategy if you like, but you don't have to: it's up to you". An everyday analogue of this strategy might be leaving an object by the front door, so that we remember to take it with us when leaving the house. Note that this strategy was not available in the earlier phase in the task because all circles apart from the upcoming one in the ongoing sequence were fixed in position and could not be dragged. After this instruction, participants performed a 1-target followed by a 3-target practice trial, then provided two more performance predictions for the two types of trial as above, then finally 20 more experimental trials split equally between the 1-target and 3-target conditions as before.

This task yielded the following measures for each condition (1-target / 3-target) within each phase: *target accuracy* (i.e. the proportion of target circles dragged to their instructed location instead of the bottom of the screen) and *predicted accuracy*. In addition, the 1-target and 3-target trials in phase 2 were associated with an intention offloading score which was defined (as in Gilbert, 2015a) as the proportion of target circles that were moved before it was their turn in the sequence minus the proportion of nontarget circles moved before their turn in the sequence. This provides a measure of the proportion of target circles that were moved into a different position in order to create a reminder, corrected for any general tendency to occasionally move the wrong circle in the sequence.

2.2.2 Prospective and Retrospective Memory Questionnaire (PRMQ)

The PRMQ (Smith et al., 2000) is a 16-item questionnaire aimed at assessing the frequency of memory failures on its two main subscales: prospective memory (e.g. Do you decide to do something in a few minutes time and then forget to do it?) and retrospective memory (e.g. Do you fail to recognize a place you have visited before?). Participants rated the frequency of their retrospective and prospective memory failures on a 1-5 scale.

2.2.3 Metacognitions Questionnaire (MQ)

To assess participants' evaluations of their own cognitive abilities, the MQ was used (Cartwright-Hatton and Wells, 1997). This scale presents participants with statements such as "I do not trust my memory" and asks them to decide the extent to which they agree with each statement on a 4-point scale. The questionnaire has 65 items consisting of 5 subscales. For the purposes of this study, only the cognitive confidence subscale was used (10 items); the remaining subscales address issues such as intrusive negative thoughts which are less relevant to the present study.

2.2.4 Cognitive Failures Questionnaire (CFQ)

Broadbent et al.'s (1982) CFQ is aimed at assessing individual differences in proneness to commonplace errors in routine activity such as noticing signposts on the road or leaving important letters unanswered. The scale has 25 items asking participants to rate how often they have experienced minor everyday errors of memory, action, and attention over the last 6 months, using a 5-point scale.

2.2.5 Implicit confidence measure

The software *FreeIAT* (http://www4.ncsu.edu/~awmeade/FreeIAT/FreeIAT.htm; Meade, 2009) was used to deliver an implicit association test (Greenwald et al., 2009, 1998) measuring the strength of participants' associations between the concepts of Self and Confidence. To do this, participants classified a set of words as relating to one of four concepts: Confident, Pessimistic, Self, and Other. In some blocks of trials participants used one response button to indicate Self or Confident and the other button for Other or Pessimistic; in other blocks of trials one of the mappings was reversed so that Self was paired with Pessimistic and Other with Confident. Insofar as participants are faster and more accurate to respond when the same response button is used for Self and Confident, compared with when Self is paired with Pessimistic, this suggests an automatic association between the concept of self and the concept of confidence.

Participants saw one word at a time in the centre of the screen, with concept labels shown at the top left and top right (see Figure 2). The position of these words indicated the correct response key (left or right) for each category and remained fixed throughout each block of trials. Following standard IAT procedures (Greenwald et al., 2003), the task included five blocks of trials, the first, second, and fourth of which were training blocks. In the first block (20 trials) participants had to classify stimulus words from the categories Self (left) and Other (right). In the second block (20 trials), words were classified from the categories Confident (left) and Pessimistic (right). In the third block (60 trials) words were classified into the categories Self or Confident (left) versus Other or Pessimistic (right). In block 4 (20 trials) participants went back to only classifying Self versus Other, but this time the response mappings were reversed (right and left, respectively). Finally, in block 5 (60 trials) participants classified Other or Confident (left) versus Self or Pessimistic (right). The words associated with each category were as follows. Confident: *convinced, correct, secure, certain, sure, assured, true, confident, accurate,* *trustworthy*; Pessimistic: *doubtful, incorrect, uncertain, inaccurate, unsure, false, erroneous, mistaken, wrong, invalid*; Self: *me, my, self, I*, and the participant's actual first name; Other: *not me, other, them, they*, and a different first name that did not belong to the participant.

[Figure 2 about here]

In each block, performance was self-paced so that the word appeared on the screen until a correct response was made, upon which the next stimulus was presented. When an incorrect response was made, a red cross was shown on the screen until the correct response was made. Results were scored using the method recommended by Greenwald, Nosek, and Banaji (2003), to yield a single implicit bias score. Positive values of this score indicate faster RTs and/or fewer errors when the same key was used for self and confident, compared with the condition where the same key was used for self and pessimistic.

2.3 Procedure

Participants first completed the three questionnaires, the order of which was counterbalanced. Next they performed the IAT, and finally the intention-offloading task. The entire experiment lasted approximately 45 minutes.

3. Results

3.1 Intention offloading task

3.1.1 Target accuracy

Results from the intention offloading task are illustrated in Figure 3. First we investigated participants' unaided performance in phase 1, when it was not possible to set reminders. We examined target accuracy in a Group (ASC, Neurotypical) x Memory Load (1 target, 3 targets) mixed ANOVA. Accuracy was higher for 1-target than 3-target trials ($F(1,50) = 5.1$, $p = .028$, $\eta^2_p = .093$), and there was also a main effect of Group ($F(1,50) = 4.8$, $p = .034$, $\eta^2_p = .087$), which did not interact with Memory Load ($F < 1$). Therefore, when reminders were disallowed, individuals with ASC performed more poorly at the task, in a manner that was not affected by memory load.

Next we investigated performance in phase 2, when participants had the option to set reminders. Intention offloading scores (i.e. the proportion of target circles for which reminders were set) were investigated in a Group x Memory Load ANOVA. The main effect of Memory Load was significant ($F(1,50) = 24.8$, $p < .001$, $\eta^2_p = .331$). This indicates that participants were more likely to set reminders when there was a higher memory load, as found by Gilbert (2015a). This effect was significant in both groups ($p < .004$) and did not differ significantly between them ($F(1,50) = .004$; $p = .95$; $\eta^2_p < .001$). The main effect of Group was not significant ($F(1,50) = 1.38$, $p = .25$, $\eta^2_p = .027$). Thus, individuals with ASC did not compensate for impaired unaided performance of the task by setting more reminders; if anything they set fewer reminders. Consistent with these effects, the difference in accuracy between the two groups was undiminished in phase 2 (Phase x Group interaction: $F(1,50) = .17$; $p = .68$; $\eta^2_p = .003$). Target accuracy continued to be significantly lower in the ASC than the neurotypical group, even when compensation was possible ($F(1,50) = 8.1$; $p = .006$; $\eta^2_p = .14$).

[Figure 3 about here]

In sum, individuals with ASC showed impaired unaided performance of the task in comparison with neurotypicals but no difference in their use of reminders. These results suggest a disconnect between unaided performance and strategy selection: despite being impaired at the task, individuals with ASC did not show a commensurate increase in compensatory behaviour. We tested formally for this disconnect as follows. Behavioural measures of target accuracy and offloading were first converted into z scores so that they were represented on comparable scales. Accuracy scores were calculated by collapsing over unaided 1-target and 3-target trials in phase 1, then subtracting the mean (across all participants) and dividing by the standard deviation. An equivalent procedure was performed for the offloading scores from phase 2. Next the z scores for the offloading measure were reversed so that positive became negative and vice versa. The reason for this is that a group that fully compensated for their impaired performance would have reduced accuracy and increased offloading; this would not indicate a disconnect between accuracy and offloading but merely an appropriate compensatory effect. Therefore, in order to avoid a compensatory pattern like this generating a significant interaction, one of the measures needs to be reversed. Finally, data were entered in to a Group (ASC, Neurotypical) x Measure (Target Accuracy, Offloading) ANOVA, which showed a significant interaction between the two factors ($F(1,50) = 6.97$, $p = .011$, $\eta^2_p = .12$). This reflected a significant group difference in target accuracy ($t(50) = 2.2$, $p = .034$, $d = .62$) but no significant difference in offloading behaviour ($t(50) = 1.2$, $p = .24$, $d = .34$).

3.1.2 Metacognitive predictions

Predicted target accuracy in the intention offloading task is shown in Figure 4. These data were analysed in a Group x Phase x Memory Load ANOVA. This showed significant main effects of Memory Load and Phase ($F(1,50) > 12.6$; $p < .001$; $\eta^2_p > .2$), as well as a significant interaction between the two factors ($F(1,50) = 17.6$; $p < .001$; $\eta^2_p = .26$). Participants predicted that their performance would be better for 1-target trials than 3-target trials, and in phase 2 compared with phase 1, especially at the higher memory load. There was also a main effect of Group ($F(1,50) = 4.7$; $p = .036$; $\eta^2_p = .085$) which did not interact with any other factor ($F(1,50) < 1.8$; $p > .18$; $\eta^2_p < .035$): individuals with ASC predicted that they would perform more poorly than neurotypicals. Thus, as well as performing less accurately than the neurotypical group, the ASC group also predicted that they would perform less accurately. In order to evaluate how well calibrated participants' predictions were to their objective accuracy, a difference score was calculated for each condition between predicted and objective accuracy. These difference scores were evaluated in a Group x Phase x Memory-Load ANOVA, showing that participants were underconfident in the three-target condition ($F(1,50) = 37.6$; $p < .00001$; $\eta^2_p = .43$) but not in the one-target condition ($F < 1$). There was no main effect of Group or significant interaction involving the Group factor ($F < 1$). Therefore, there was no evidence that the groups differed in the accuracy of their metacognitive predictions.

[Figure 4 about here]

3.2 Questionnaire measures

Results of the questionnaire measures are shown in Table 2. For each of these explicit self-report measures, individuals with ASC rated their abilities to be significantly poorer than the neurotypical group.

[Table 2 about here]

3.3 Implicit metacognitive confidence

IAT scores were significantly different from zero in both groups (Neurotypical: $t(23) = 6.1$, $p < .00001$, $d = 2.5$; ASC: $t(26) = 7.0$, $p < .00001$, $d = 2.7$), indicating that response times were faster when self- and confidence-related words were mapped onto the same response key rather than when self- and pessimism-related words were mapped onto the same response key. This suggests a positive self-confidence bias in both groups, i.e. it was easier to associate the concept of being correct with oneself than being incorrect. However, it should be noted that this could also reflect an order effect since the block where self and confident were mapped onto the same key was always performed first. The two groups did not differ significantly in IAT scores ($t(50) = .54$, $p = .60$, $d = .15$). Therefore, although the ASC group showed reduced confidence on all explicit measures, they did not show a significant difference on the IAT measure. This discrepancy between the explicit and implicit measures of confidence was confirmed by converting the IAT measure into a z score, and doing the same for each of the explicit (questionnaire) measures. The IAT z score was reversed, seeing as it is scored in the opposite direction to the explicit measures. The explicit measures were then averaged and the resulting z scores entered into an ANOVA with factors Group (ASC, Neurotypical) and Measure (explicit, implicit). This showed a significant Group x Measure interaction ($F(1,50) = 5.8$; $p = .02$; $\eta^2_p = .10$), reflecting the significant group difference in explicit measures (t(50)

= 3.5, $p < .001$, $d = .99$) but absence of a significant group difference in the implicit IAT measure (as described above).

3.4 Correlations between measures

Finally, in an exploratory analysis, correlations between the various measures were calculated. Results are shown in Table 3 (collapsing across all participants) and Table 4 (separately for the two groups). For these analyses 1-target and 3-target intention offloading trials were collapsed. We note that the IAT measure was positively correlated with participants' performance predictions in the unaided phase of the intention offloading task and negatively correlated with participants' offloading behaviour in the second phase (i.e. participants with lower implicit confidence scores explicitly predicted poorer performance in phase 1 and set more reminders in phase 2). This supports our use of the IAT score as a measure of implicit confidence. If we collapse over the explicit questionnaire confidence measures (which are conceptually related to each other and positively intercorrelated) and then conduct a Bonferroni correction over the six resulting measures from Table 3 with which the IAT measure can be correlated, this results in a significant positive relationship with phase 1 predictions ($p_{corrected} = .042$) and a marginally-significant negative relationship with phase 2 offloading behaviour ($p_{corrected} = .06$). Nevertheless, given the novelty of the IAT measure, we consider these results exploratory until they can be replicated in an independent sample.

[Table 3 about here]

Note also that the offloading score did not correlate significantly with performance in phase 2, which may seem surprising given that offloading may putatively be used as a compensatory mechanism to improve performance. A similar result was found in Gilbert (2015b), where it was argued that this reflects two opposing effects cancelling out: on the one hand offloading should improve performance (leading to a positive relationship between offloading and phase 2 accuracy); on the other, individuals who offload the most may be those with lowest ability (leading to a negative relationship). Therefore, in order to investigate the influence of offloading on performance, the relationship between offloading and phase 2 accuracy should be investigated after controlling for phase 1 accuracy (i.e. unaided ability), using multiple regression (see Gilbert, 2015b for further discussion of this point). This analysis (predicting phase 2 accuracy from both phase 1 accuracy and phase 2 offloading behaviour in a single model) showed significant effects of both measures ($t(49) > 2.04$; $p < .046$), replicating the earlier study and indicating that offloading was indeed beneficial to performance.

[Table 4 about here]

4. Discussion

This study investigated a task requiring participants to remember intentions over a brief delay. Individuals with ASC performed more poorly than age- and IQ-matched neurotypical control participants. Subsequently, when participants were told that they were free to set reminders if they wished, the two groups set a comparable number of reminders and the ASC group still performed more poorly than the neurotypical group. Therefore, individuals with ASC did not compensate for impaired performance. This absence of strategic compensation was observed even though the ASC group was not overconfident in comparison with the neurotypical group, according to explicit performance predictions and questionnaire self-evaluations.

4.1 Intention offloading task: unaided performance

Results from the first (unaided) phase of the intention offloading task were consistent with previous studies of prospective memory, which have typically shown less accurate performance in individuals with ASC than neurotypicals (Altgassen et al., 2012, 2009; Brandimonte et al., 2011; Henry et al., 2014; Jones et al., 2011; Kretschmer et al., 2014; Mackinlay et al., 2006; Rajendran et al., 2011; Sheppard et al., 2016; Williams et al., 2013, 2014; Yi et al., 2014). Thus, the present study adds to a growing literature suggesting that individuals with ASC have difficulty performing prospective memory tasks. The retention interval in the present intention offloading paradigm (i.e. the time between encoding an intention and executing it) was much shorter than standard paradigms (see Gilbert, 2015a for discussion of this). This suggests that individuals with ASC may have difficulty executing delayed intentions across a wide variety of timescales, not only when memory processes operate over a relatively long timeframe (as in previous studies) but also when short-term memory processes akin to those required in working memory tasks are required.

4.2 Intention offloading task: strategic compensation

The main novel aspect of the present study was to examine a task in which participants had the opportunity to set external reminders, in order to examine whether any difference between the groups in their performance of the task would persist when strategic compensation was possible. We now consider six potential (non-mutually-exclusive) explanations for why it was that the ASC group did not appear to compensate for impaired performance of the task.

4.2.1 Do individuals with ASC understand the benefit of using external reminders?

Both the neurotypical and ASC groups set significantly more reminders in the 3-target than the 1-target condition. This pattern of results has previously been argued to reflect a metacognitive evaluation of demand (Gilbert, 2015a; Risko and Gilbert, 2016). The magnitude of this effect was almost identical in the two groups. This suggests that in both groups there was similar understanding that the 3-target trials are more difficult than the 1-target trials, and a similar influence of this insight on strategic behaviour. Therefore, it is unlikely that individuals in the ASC group simply failed to understand that using external reminders can compensate for difficulty performing the task.

4.2.2 Are individuals with ASC overconfident about their ability to perform the task?

One possible explanation of the failure of individuals with ASC to compensate for impaired performance of the intention offloading task is that they did not believe their unaided performance to be any worse than the neurotypical group. This seems unlikely. At the group level, as well as performing worse than the neurotypical group, the ASC group also predicted that their performance would be worse. As a result, the performance predictions of the ASC group were no less accurate than those of the neurotypical group. The ASC group's evaluation of their abilities in the questionnaire measures was also less confident than the neurotypical group. This suggests that the individuals with ASC were not overconfident in their ability to perform the task, in comparison with the neurotypical individuals.

4.2.3 Did the groups differ in their tendency to translate metacognitive evaluations into strategic behaviour?

While the groups may have calibrated their performance predictions to objective ability in a similar manner, it is possible that the groups differed in their tendency to translate these predictions into strategic behaviour. In other words, the groups may have had similar metacognitive knowledge about their own abilities and the difficulty of the task but dissimilar metacognitive control, i.e. use of that knowledge to inform strategic behaviour (Dunlosky and Connor, 1997; Grainger et al., 2016). This seems a possible explanation of the present results. However, metacognitive control in the individuals with ASC is clearly not atypical in all respects. As discussed above, both groups predicted that performance on 3-target trials would be inferior to 1-target trials, and showed a commensurate increase in their use of reminders in the more difficult condition. The equivalent difference in strategy choice between the two conditions suggests similar metacognitive control in the two groups. Therefore, the present results do not support a hypothesis of reduced metacognitive control across all circumstances in ASC. However, they may be compatible with a more limited effect.

4.2.4 Do the present results support a distinction between explicit and implicit confidence?

All explicit measures - i.e. questionnaires and direct performance predictions - indicated significantly lower confidence in the ASC than the neurotypical group. However, the implicit measure of confidence (based on an implicit association test) did not differ significantly between the groups. In this respect, intention offloading behaviour was more reflective of implicit confidence than explicit confidence, seeing as it also did not differ significantly between groups. This raises the possibility of a distinction between implicit and explicit confidence such that intention offloading behaviour is more closely related to the former than the latter. Supporting this possibility is the inverse relationship between implicit confidence and offloading behaviour (significant both in the ASC group alone and after collapsing over the two groups, but not in the neurotypical group when considered individually). This could explain why the two groups set a similar number of reminders despite the lower explicit confidence of the ASC group: although individuals with ASC may have learned to moderate their explicit judgements of their ability levels, this may not extend to implicit representations of self-confidence. In this way, representations of self-confidence might be akin to other representations of mental states which differ between individuals with ASC and neurotypicals in a manner that depends on whether they are tested explicitly or implicitly (Senju, 2013). We offer this hypothesis tentatively. Given the novelty of implicit confidence measure, the fact that the two conditions of the IAT were presented in fixed order rather than counterbalanced, we regard this as a speculative possibility that requires further investigation, rather than drawing strong conclusions at present.

4.2.5 Might individuals with ASC be less willing to switch strategies?

Participants completed the intention offloading task in two phases: first without being able to set reminders and subsequently with the option to do so. Therefore, insofar as participants set reminders in phase two, this constituted a switch away from the no-reminder strategy used in the previous phase. Previous studies have suggested reductions in cognitive flexibility in individuals with ASC (Hill, 2004a), especially when behavioural switches need to be self-initiated rather than being directly instructed (Hill and Bird, 2006; White et al., 2009). Therefore one potential explanation for the lack of compensatory intention offloading in the ASC group might be that participants in this group were less willing, once they had completed part of the task using an unaided strategy, to switch to an alternative strategy of using reminders. This might account for underuse of reminders in the ASC group. However, it should be noted that individuals with ASC were just as likely as neurotypicals to switch strategy between trials with one target versus three targets, setting more reminders in the latter condition. Therefore individuals with ASC were clearly not inflexible in all respects.

4.2.6 Might the groups have differed in the level of performance they considered to be acceptable?

One final possibility to be considered is that individuals in the ASC group did not compensate for reduced unaided accuracy simply because they considered it more acceptable to miss targets. This could especially be the case seeing as their performance was nevertheless high, and the neurotypical group was close to ceiling. The explicit instructions given to participants in this study were straightforward: on each trial, they were told to produce a particular behaviour (e.g. 'please drag 5 to the left'). No further explicit instructions were provided. However, like most psychology experiments this study involved a social encounter between an experimenter and participant, in which both explicit and implicit task requirements were communicated (Roepstorff and Frith, 2004). For example, it would have been reasonable for participants to assume that it is acceptable to make a small number of errors in the course of the experiment, but not to entirely disregard the task instructions. It is conceivable that individuals with ASC formed a different model of the implicit task demands (see White, 2013 for further discussion of this point), or differed in their motivation to perform the task accurately. For example, they may have thought that they were 'supposed' to perform the task less well than neurotypicals, or felt less motivated by the social reward of pleasing the experimenter by following the instructions provided. This could explain why they did not compensate for impaired unaided performance of the task by setting more reminders. We cannot exclude this possibility. However, it is hard to reconcile with the matched performance of the two groups on the IQ measures, ruling out a generalised difference between the two groups in willingness to engage with experimental tasks. One way to test this hypothesis would be to repeat the experiment using a different form of reward (e.g. monetary payment contingent on accurate performance of the task), to see whether this affects participants' willingness to use strategies to improve task performance. It would also be useful to examine whether similar results are found using more difficult paradigms in which accuracy would be reduced from the near-ceiling levels found in the present study.

4.3 Conclusion

Individuals with ASC show a complex pattern of strengths and weaknesses in experimental tasks (Happé et al., 2006; Minshew et al., 1997; Towgood et al., 2009), and a range of functional outcomes in everyday life (Ozonoff et al., 2004). One factor that has been hypothesised to underlie some of this variability is the extent to which individuals engage in strategic behaviours or compensatory learning, which can potentially camouflage any underlying difficulties (Frith, 2004; White et al., 2014). The present results indicate that even when strategies are available, and participants are explicitly instructed that they are free to use them, it is not inevitable that individuals with ASC will compensate for impaired unaided performance of a task. This absence of strategic compensation was not attributable to impaired metacognitive evaluation, at least as measured in explicit performance predictions and self-ratings. Individuals with ASC showed good metacognitive insight into their abilities: they were no less accurate than neurotypicals at judging their own performance levels and they appropriately increased their use of external strategies as task demands increased. Therefore just because, at the group level, individuals with ASC may have less confidence in their ability to perform an experimental task, this does not necessarily translate into increased compensatory behaviour. We suggest that this may relate to at least four possible factors: reduced influence of metacognitive evaluations on strategy choice, discrepancies between implicit and explicit representations of confidence, difficulty switching from one strategy to another, and differential interpretation of implicit task demands when engaging in experimental tasks.

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Figure Captions

Figure 1. Schematic illustration of the intention offloading task.

Figure 2. Schematic illustration of the implicit association test. In panels A and B the same response key is used for the concepts of 'self' and 'confidence' (compatible mapping); in panel C these concepts are mapped onto different response keys (incompatible mapping). Insofar as participants are faster to respond using the compatible versus incompatible mapping, this suggests implicit self-confidence.

Figure 3. Results from the intention offloading task: accuracy measures. Error bars indicate standard error of the mean.

Figure 4. Results from the intention offloading task: metacognitive measures. Error bars indicate standard error of the mean.

Table 1. Participant demographics and background variables.

	ASC (n = 28)		Neurotypical (n = 24)		*t* test
	Mean (SD)	Range	Mean (SD)	Range	*p* value
Age (years)	28.5 (6.1)	18 - 38	27.8 (6.0)	19 - 40	0.68
Fullscale IQ	118.4 (14.3)	89 - 152	121.9 (14.7)	98 - 151	0.39
Verbal IQ	121.1 (15.8)	85 - 155	123.3 (15.3)	96 - 150	0.60
Performance IQ	111.8 (13.5)	87 - 132	114.9 (15.1)	80 - 148	0.43
ADOS: total	8.8 (2.8)	4 - 17			
ADOS: communication	2.7 (1.4)	1 - 6			
ADOS: social interaction	6.1 (1.8)	2 - 11			
Gender	4 F; 24 M		6 F; 18 M		
Handedness	4 L; 24 R		2 L; 22 R		

Table 2. Metacognitive measures. Note that higher scores indicate higher confidence in the implicit measure (confidence IAT) but lower confidence in the other measures.

	ASC mean (SD)	Neurotypical mean (SD)	Comparison
Confidence IAT	.459 (.340)	.408 (.329)	$t(50) = .54$, $p = .60$, $d = .15$
PRMQ (prospective)	22.6 (6.3)	18.9 (3.7)	$t(50) = 2.5$, $p = .02$, $d = .71$
PRMQ (retrospective)	20.6 (6.2)	16.4 (3.5)	$t(50) = 2.9$, $p = .005$, $d = .82$
MQ	20.4 (4.9)	16.1 (4.2)	$t(50) = 3.4$, $p = .001$, $d = .96$
CFQ	47.5 (12.2)	38.0 (10.9)	$t(50) = 2.9$, $p = .005$, $d = .82$

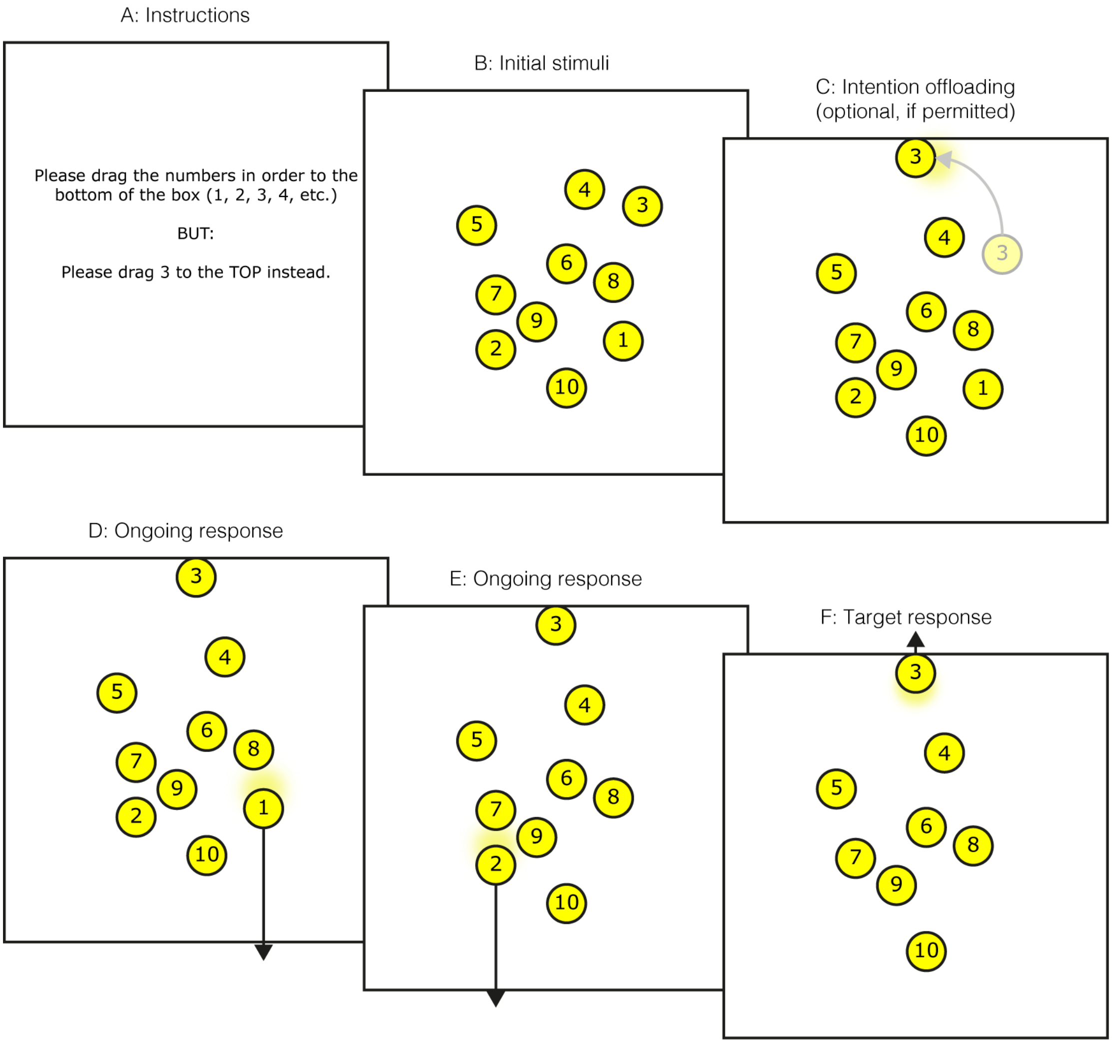
Table 3. Correlations between measures (collapsed across all participants). # = p < .1; * = p < .05; ** = p < .01; *** = p < .001. CogFail = Cognitive Failures Questionnaire. MetaQ = Metacognitions Questionnaire. PM-PRMQ = prospective memory scale, prospective and retrospective memory questionnaire; RM-PRMQ = retrospective memory scale, prospective and retrospective memory questionnaire. IAT = implicit association test (implicit measure of confidence).

	Phase 1 prediction	Phase 1 performance	Phase 2 prediction	Phase 2 performance	Offloading	CogFail	MetaQ	PM-PRMQ	RM-PRMQ	IAT
Phase 1 prediction	-	.47***	.71***	.25#	-.14	-.08	-.17	-.25#	-.16	.38**
Phase 1 performance		-	.62***	.57***	-.14	.00	-.10	-.10	-.05	.07
Phase 2 prediction			-	.52***	.04	-.03	-.19	-.20	-.10	.16
Phase 2 performance				-	.15	-.06	.-04	-.05	-.10	.02
Offloading					-	-.27#	-.26#	-.16	-.19	-.36**
CogFail						-	.60***	.65***	.67***	.14
MetaQ							-	.60***	.57***	.08
PM-PRMQ								-	.79***	-.09
RM-PRMQ									-	-.01
IAT										-

Table 4. Correlations between measures. Results from the neurotypical group are shown in red (top right) and results from the ASC group are shown in blue (bottom left). # = p < .1; * = p < .05; ** = p < .01; *** = p < .001. CogFail = Cognitive Failures Questionnaire. MetaQ = Metacognitions Questionnaire. PM-PRMQ = prospective memory scale, prospective and retrospective memory questionnaire; RM-PRMQ = retrospective memory scale, prospective and retrospective memory questionnaire. IAT = implicit association test (implicit measure of confidence).

	Phase 1 prediction	Phase 1 performance	Phase 2 prediction	Phase 2 performance	Offloading	CogFail	MetaQ	PM-PRMQ	RM-PRMQ	IAT
Phase 1 prediction	-	.31	.74***	-.03	-.07	.00	-.25	-.29	.08	.33
Phase 1 performance	.49**	-	.34	.30	-.16	-.09	.15	-.34	-.20	-.18
Phase 2 prediction	.71***	.65***	-	.16	-.02	.10	-.07	-.12	.19	.16
Phase 2 performance	.29	.62***	.56**	-	.10	.07	.37#	.03	-.13	.01
Offloading	-.25	-.24	-.01	.09	-	-.31	.01	.10	-.15	-.24
CogFail	.02	.25	.12	.12	-.16	-	.22	.32	.42*	.21
MetaQ	.00	-.01	-.06	.00	-.38*	.72***	-	.30	.38#	-.25
PM-PRMQ	-.16	.10	-.10	.11	-.23	.73***	.65***	-	.46*	-.27
RM-PRMQ	-.14	.15	.00	.11	-.14	.72***	.55**	.84***	-	-.04
IAT	.46*	.25	.23	.08	-.44*	.05	.28	-.06	-.04	-

Figure 1



A: Instructions
Please drag the numbers in order to the bottom of the box (1, 2, 3, 4, etc.)
BUT:
Please drag 3 to the TOP instead.
B: Initial stimuli
4
3
5
6
8
7
9
1
2
10
C: Intention offloading (optional, if permitted)
3
4
3
5
6
8
7
9
1
2
10
D: Ongoing response
3
4
5
6
8
7
9
1
2
10
E: Ongoing response
3
4
5
6
8
7
9
2
10
F: Target response
3
4
5
6
8
7
9
10

Figure 2

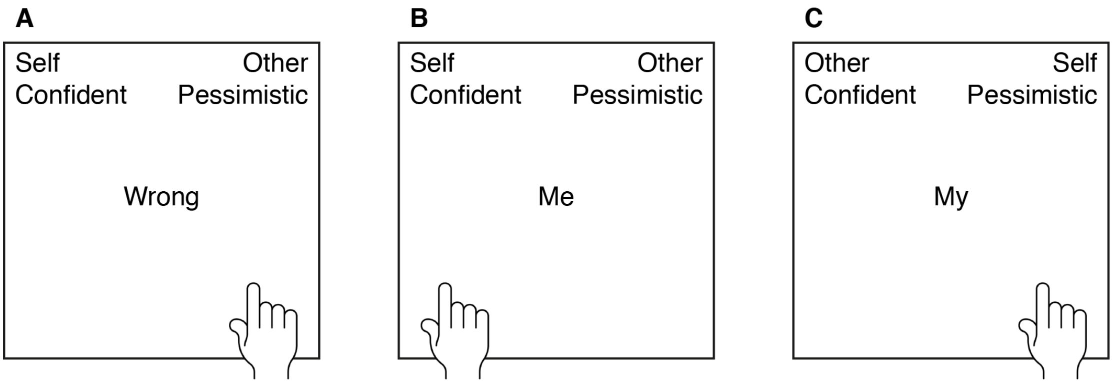

A
Self
Other
Confident
Pessimistic
Wrong
B
Self
Other
Confident
Pessimistic
Me
C
Other
Self
Confident
Pessimistic
My

Figure 3

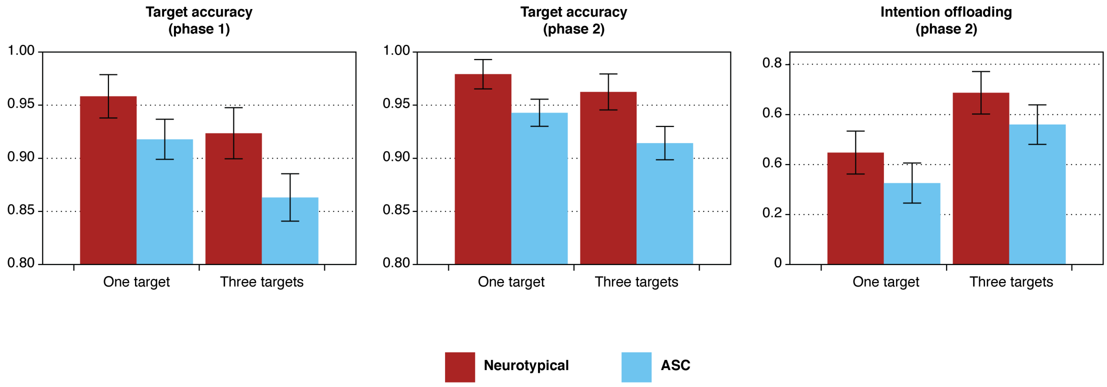
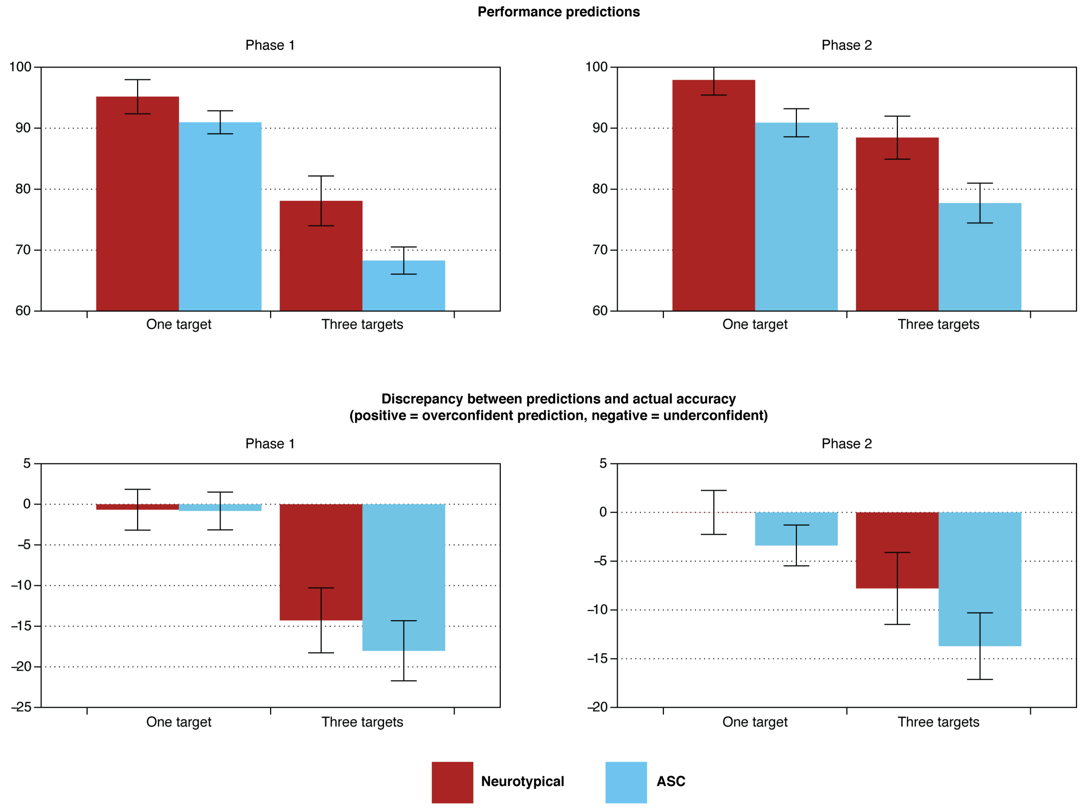

Target accuracy
(phase 1)
1.00
0.95
0.90
0.85
0.80
One target
Three targets
Target accuracy
(phase 2)
1.00
0.95
0.90
0.85
0.80
One target
Three targets
Intention offloading
(phase 2)
0.8
0.6
0.6
0.2
0
One target
Three targets
Neurotypical
ASC

Figure 4



Performance predictions
Phase 1
Phase 2
100
90
80
70
60
One target
Three targets
Discrepancy between predictions and actual accuracy
(positive = overconfident prediction, negative = underconfident)
5
0
–5
–10
–15
–20
–25
Neurotypical
ASC